Simultaneous Real Time Micro-bathymetric Data from a Laser Line Scanning System and Acoustic Backscatter

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LONG TERM OBJECTIVE

The long term objective of this research is to understand the processes that are involved in the temporal and spatial scales of the evolution of the microbathymetry of the sea floor. As part of the high frequency acoustic backscatter program, the results of our bottom bathymetry will be used by acousticians in order to validate physical models which aim to provide an understanding of the interaction of sound with the sea floor.

SCIENTIFIC/TECHNICAL OBJECTIVES

The objective is to remotely measure high-resolution bathymetry of the seafloor using optical methods inherent in laser line scanning systems and to obtain a unique data set of submillimeter bathymetric and spatial resolution topography of the seafloor, and to measure the manner in which it changes over an extended period of time under natural environmental conditions. The resulting high-resolution topographic information is used to assist in understanding the high frequency acoustic backscatter signal as function of natural seafloor morphology.   In particular, acousticians interested in the high frequency backscatter of sound would like to understand the relative amounts of surface to volume scattering. Surface roughness is an important quantity which needs to be measured in order to judge the relative contributions of each.

APPROACH

Our approach to provide high-resolution bathymetric measurements of the seafloor is to utilize the *3D Sea Scan* laser line scan system. The *3D Sea Scan* system normally operates in a tow mode configuration and scans athwartships to its direction of motion. To investigate the topographic characteristics of the same seafloor area over an extended period of time, a special Underwater Translation Device (UTD) was constructed to rigidly support the laser line scan system and control its position over the area of interest.

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14. ABSTRACT
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TASKS COMPLETED

The work completed for this project has been threefold; (i) calibration and characterization of the system for high resolution bathymetry, (ii) investigating the integrity of the data (filtering of in-water events, correction for pointing error) and (iii) processing and analysis of the data (investigation of decorrelation rates at different spatial frequencies, time-evolution of bottom roughness spectra)

RESULTS

This year has been spent analyzing data that was collected at the SAX site during the experiment. Results presented here include both the measurement of the detailed bottom topography and its time evolution. An important aspect of our analysis is also the estimation of errors in these quantities. Although in a program supported the Environmental Ocean Optics program, a rigorous calibration of the system was performed, in the SAX experiment considered here many narrow scan profiles of the seafloor (~1.35 m long by 1.3 mm wide) were taken over a 9-day period. Hence scanning a slightly different area due to attitude variations in the system from environmental effects was inevitable. Fortunately, however, the degree of bathymetric error due to attitude variations in the instrument was found to be relatively small given the environment and nature of the experiment.

The procedure for computing the bathymetric error consisted of computing the variability in bottom relief as a function of range between two points on the sea floor. Since the instrument system carried a set of sensors to measure yaw, pitch and roll, the estimated variability in the sea floor as a function of instrument motion when coupled with the observed variability permitted the computation of the error due to these changes. A more complete description is contained in [1]. The amount of decorrelation was computed as a function of time and the error bounds were also estimated in order to provide not only an estimate of bottom decorrelation but also the expected error in as a function of the environmental conditions. Figure 1 shows the decorrleation and also the estimated errors.
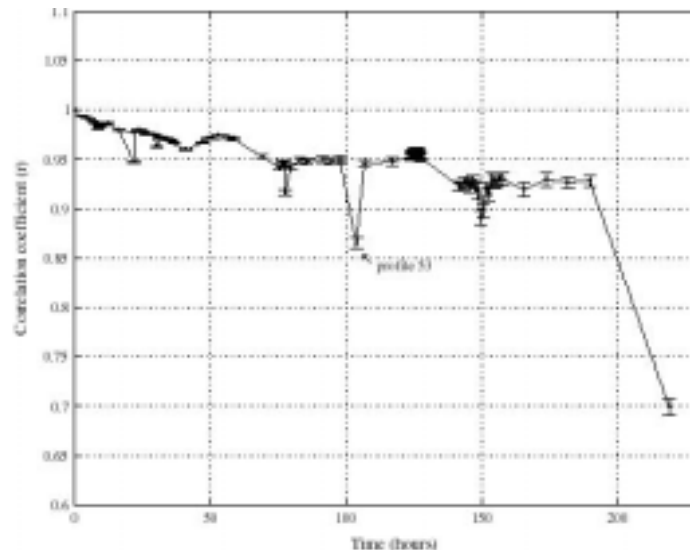

Fig. 1. Decorrelation coefficient and error bounds of bottom profiles. Profiles are referenced with respect to the first profile in the series.

Next, in order to look at the degree of spatial variability in the bottom, the bottom profile was divided into a number of sections (2a) and the decorrelation coefficient was computed. Fig. 2b indicates that there was no particular preference of these spurious outlier values to occur in either crest or troughs.
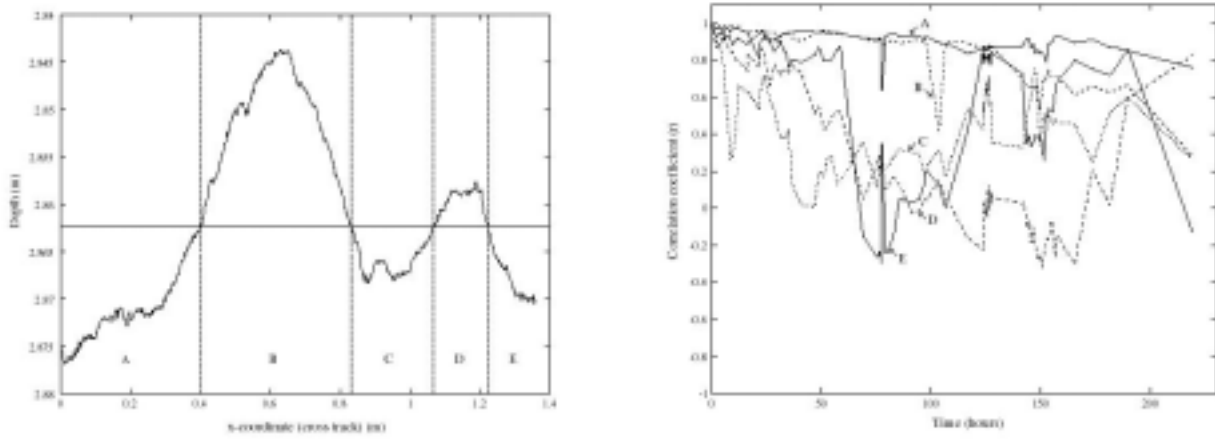

Figure 2 (a) Sectioning of the profile into crests and troughs. (b). Decorrelation of the different sections defined defined in (a).

In addition, the bottom roughness spectra were calculated in order to provide data on the time-evolution of bottom roughness. To estimate the bottom roughness, the power spectrum of each profile in the time series was calculated using conventional techniques [Welch's method]. Figure 3 shows the mean power spectrum for all profiles with error bars indicating the standard deviation. (Accuracy of individual spectra is $\sim \pm 1$ dB). The data appear to be linear in these log-log plots with the exception of the lowest frequencies (0.0074 – 0.022 cycles/cm) which show significantly higher spectral strengths.
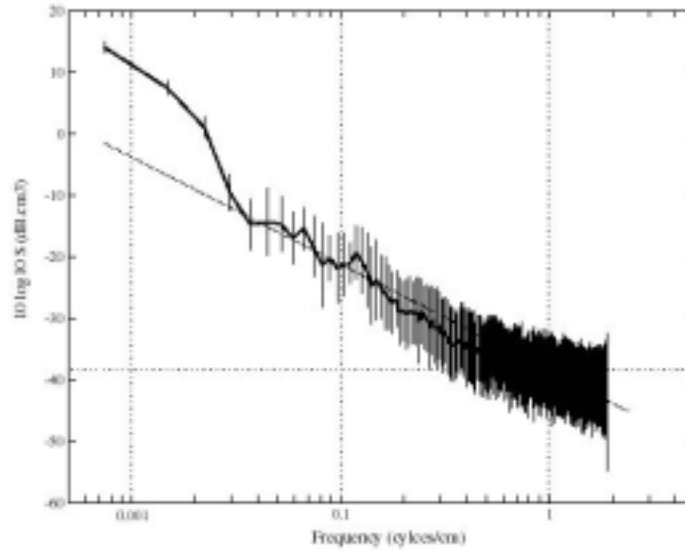

Fig. 3. Mean roughness spectra for all profiles. Error bars indicate standard deviation.

In Figure 4 the time-evolution of the spectral slopes and intercepts of these profiles are shown. The intercept (a) shows a marginal increase in power as the experiment progresses while the slope (b) exhibits a more pronounced yet small increase (becomes less negative) over time. This may be interpreted in the simplest sense as an erosion of the sand wave amplitude with an accompanying marginal increase in small-scale roughness. The last point corresponds to an encroaching storm with a value closer to the observed original values at the start of the experiment.
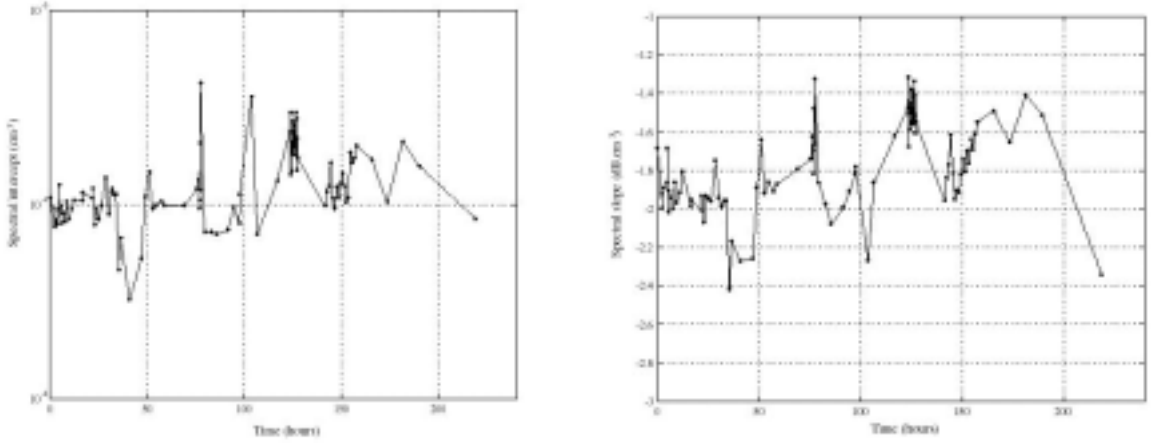

Fig. 4: Time-evolution of spectral intercept (a) and slope (b) of bottom roughness.

In addition, transects were examined to see how the seafloor decorrelated at different spatial scales. Figure 5 shows the decorrelation rate of 9 frequency bands (FB0 – FB8). The technique used consisted of filtering the Fourier Transform of each profile in order to produce a real space bathymetric profile which spanned only a narrow band of spatial frequencies. Subsequent calculation of the correlation coefficient yielded the resolution dependent correlation coefficient. [Frequency bands (samples/cm): FB0 (0.0074-0.022), FB1 (0.015-0.03), FB2 (0.03-0.044), FB3 (0.044-0.067), FB4 (0.067-0.1), FB5 (0.1-0.2), FB6 (0.2-0.3), FB7 (0.3-1.0), FB8 (1-1.89)].
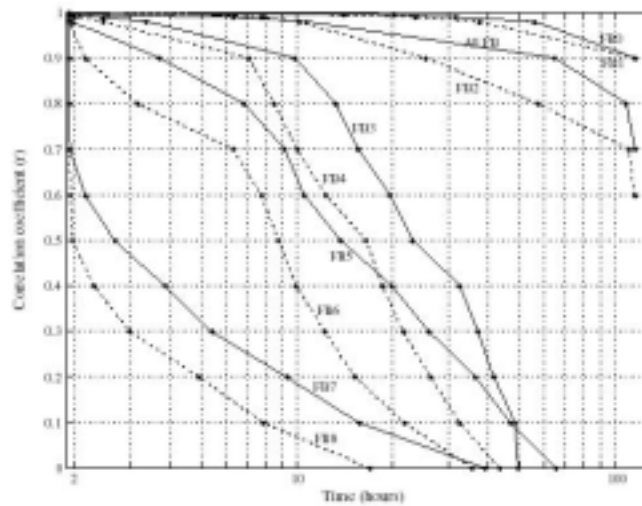

Fig.5. Decorrelation coefficient as a function of spatial frequency.

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Fig. 5 reveals that decorrelation rates are much faster for the higher frequencies than the lowest frequencies. Moreover, the low frequencies are observed to initially decorrelate slowly and then speed up, whereas the higher frequencies tend to decorrelate rapidly at first and then slow as complete decorrelation is approached.

Overall results indicate that changes in the seafloor topography appeared to be dominated by two mechanisms; (i) a ubiquitous, consistent gradual erosion of the sand wave amplitude over time accompanied by a marginal increase high-frequency bottom roughness, and (ii) sudden, significant perturbations of the seafloor topography and their general recovery to initial conditions. An interesting question that can be asked is whether the changes in bottom are primarily due to currents, animals, or some combination of both. In order to address this, we analyzed data from an S4 current meter which was deployed at the site. Interestingly, current never exceeded the threshold orbital velocity for the observed sediment sand grains. This led us to conclude that the major source of bottom changes were the result of animal activities. These activities include the diurnal migration of benthic animals that emerge into the water column en masse during darker hours and their return to the benthos. Overlying this gradual or accumulative erosion process are the activities of larger animals, such as the feeding behavior of fish, which is marked by the significant and transient changes observed in the data.

IMPACT

A new high-resolution bottom bathymetry system based on triangulation and scanning laser technology was deployed as part of the SAX99 experiment. Useful data was produced over a period of several weeks.

TRANSITIONS

This program, itself, represents a transition from the environmental optics program, which paid for its development. Our results are also being used by the acousticians to analyze their time varying data.

RELATED PROJECTS

A related project is the development program funded by Dr. Steve Ackleson of the environmental ocean optics division which supported the development of this system.

PUBLICATIONS

[1] Moore, K. D and Jaffe, J. S.: Time-evolution of high-resolution topographic measurements of the seafloor using a 3D laser line scan mapping system. IEEE J. Oceanic Eng. (in revision, 2001).

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